THE ASTROLABE

This scientific instrument of the Middle Ages was used for both astronomical and terrestrial observations. It also served as an analogue computer, particularly for determining the local time

by J. D. North

The astrolabe was the most widely used astronomical instrument of the Middle Ages. It originated in antiquity and was still not uncommon in the 17th century. One purpose of the instrument was observational: it was employed for finding the angle of the sun, the moon, the planets or the stars above the horizon or from the zenith. It could also be used for determining the height of mountains and towers or the depths of wells and for surveying in general. Far more important, however, was the astrolabe's value as an auxiliary computing device. It enabled the astronomer to work out the position of the sun and principal stars with respect to the meridian as well as the horizon, to find his geographical latitude and the direction of true north (even by day, when the stars were not visible), and it allowed him to indulge in such prestigious and lucrative duties as the casting of horoscopes. Above all, in the days before re-

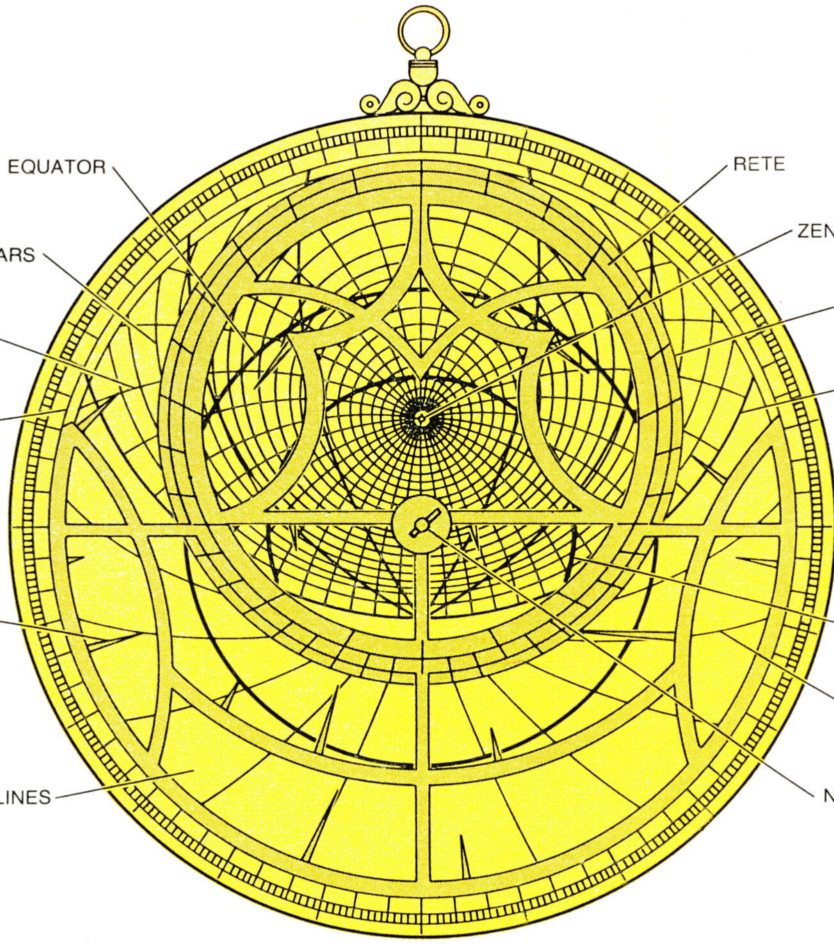


DIAGRAM OF THE FRONT OF AN ASTROLABE shows those parts that were central to its function as an instrument for calculation. The fretted network, known as the rete, is a reproduction of the heavens. The tiny pointers indicate the positions of the stars. The eccentric circle at the top is the ecliptic: the yearly path of the sun through the sky. The rete pivots around a pin that holds it to the plate behind it. The pin's position corresponded to the north celestial pole. The lines on the plate represent coordinate lines that are fixed with respect to an observer on the earth. The turning of the rete showed the daily motions of stars in relation to observer.

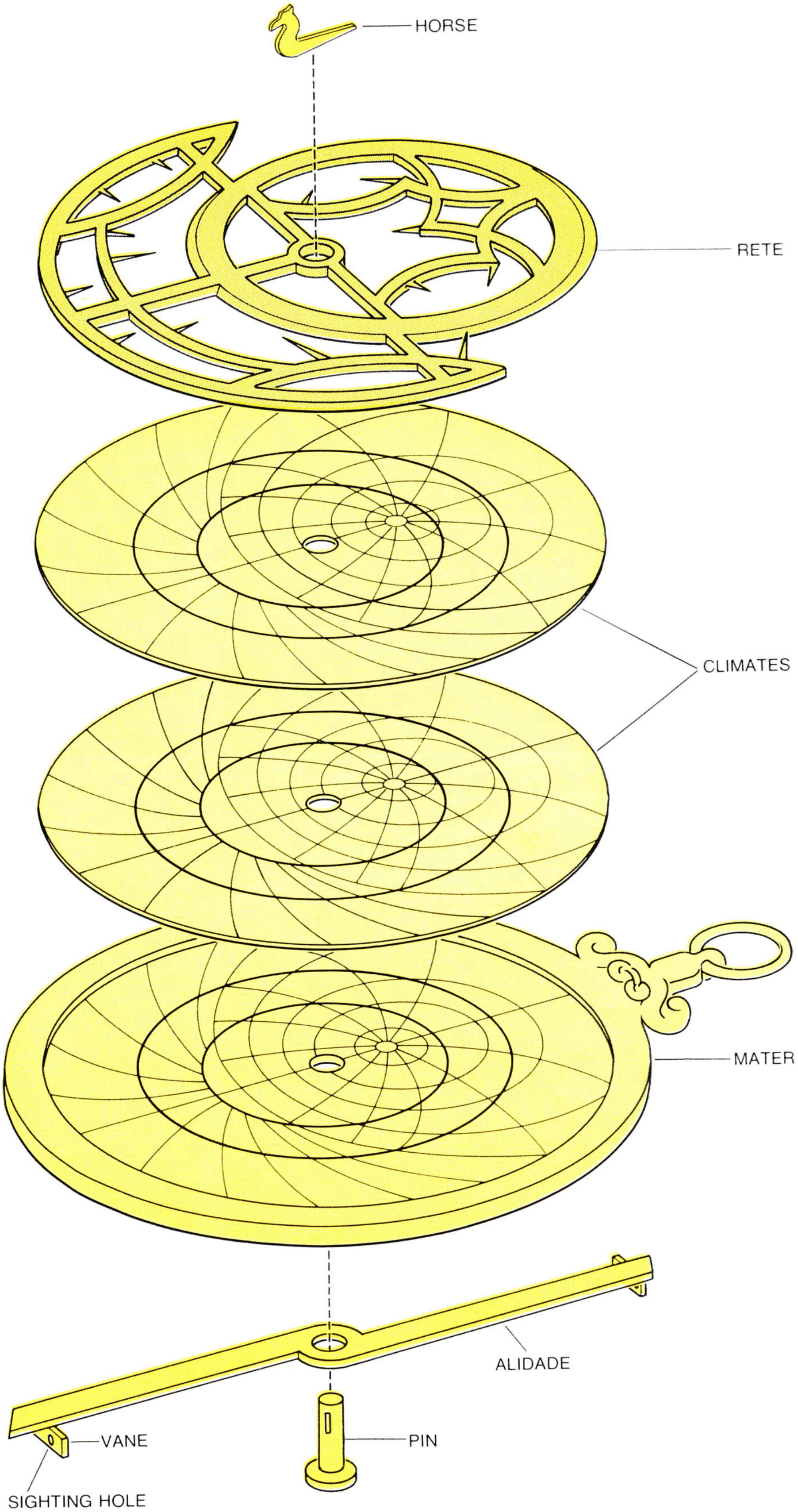
liable clocks were commonly available, the astrolabe provided its owner with a means of telling time by day or by night, as long as the sun or some recognizable star marked on the instrument was visible.

A more precise name for the instrument I am describing is the planispheric astrolabe. There are three other types of astrolabe: the linear astrolabe, the spherical astrolabe and the mariner's astrolabe. The linear astrolabe was an instrument that was difficult both to use and to understand, and it was rarely made. The spherical astrolabe was also rare; it was in the form of a globe, although it had much in common with the flat planispheric astrolabe. The mariner's astrolabe was a relatively late instrument; as far as is known it was first used only a little before the time of Columbus. It was a crude device, serving chiefly to find the altitude of the sun, moon or stars above the horizon, and it was used for much the same purpose as the sextant of later centuries. Basically it consisted of an alidade, or straight rule, pivoted centrally on a single pin on a circular plate. On each end of the alidade was a vane pierced with a hole. The mariner hung the instrument from his thumb and adjusted the alidade so that he could sight the celestial object through the holes in the vanes. He then read the altitude of the object on the scale of degrees around the edge. (In working with the sun he would have allowed one vane to cast a shadow on the other in order not to injure his eyes by direct observation.) The mariner's astrolabe was made of heavy brass so that it would hang steadily from its ring and shackle, and it was also pierced so that the wind would affect it as little as possible.

The planispheric astrolabe I shall henceforth call simply the astrolabe, since it was by far the commonest type. In order to fully understand even its simple uses, it is necessary to examine its outward form and trace how it acquired that form.

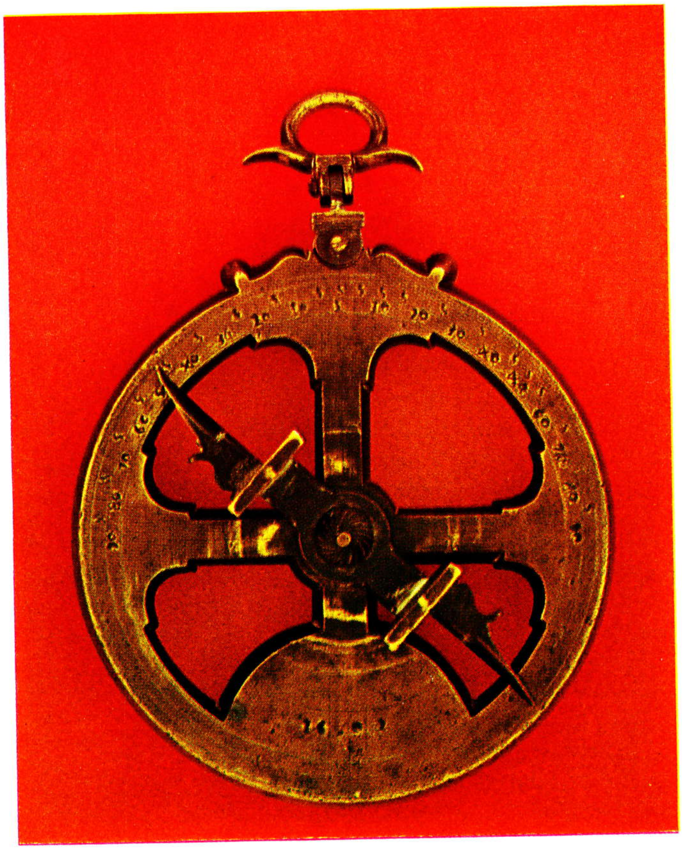
Both sides of the astrolabe bore valuable information. Generally speaking, the alidade was pivoted on the back. The back was a repository for information that could in principle have been stored elsewhere. It usually carried a number of scales and tables whose precise nature tended to change from century to century.

A scale that is found on almost all astrolabes is the calendar scale, which represented the days and months and correlated the position of the sun with



EXPLODED VIEW OF AN ASTROLABE shows the relationship of its various parts. The mater ("mother") is the main body of the astrolabe. The climates are plates engraved with coordinate lines for different latitudes, usually those to which the observer might travel. The alidade is a straight rule that was used for sighting celestial objects and finding their altitude. It was held to the back of the astrolabe (*see illustration on page 105*) and was free to rotate like the rete. The rete fits over all the climates, which are contained within the mater. The pin slides through the centers of all the plates and is secured by the horse, a wedge whose thicker end was traditionally in the form of a horse's head. Some astrolabes had no loose plates; in such instruments the mater was engraved as the one and only climate.

PERSIAN ASTROLABE was made in the 12th century. It is 5⅛ inches across and is of fairly simple design, as are most early astrolabes. Rete is regular and star pointers are straight and unadorned.



MARINER'S ASTROLABE was a crude device used chiefly to find the altitude of celestial bodies above the horizon. Alidade is on the front. This astrolabe is probably Spanish and is dated 1602.

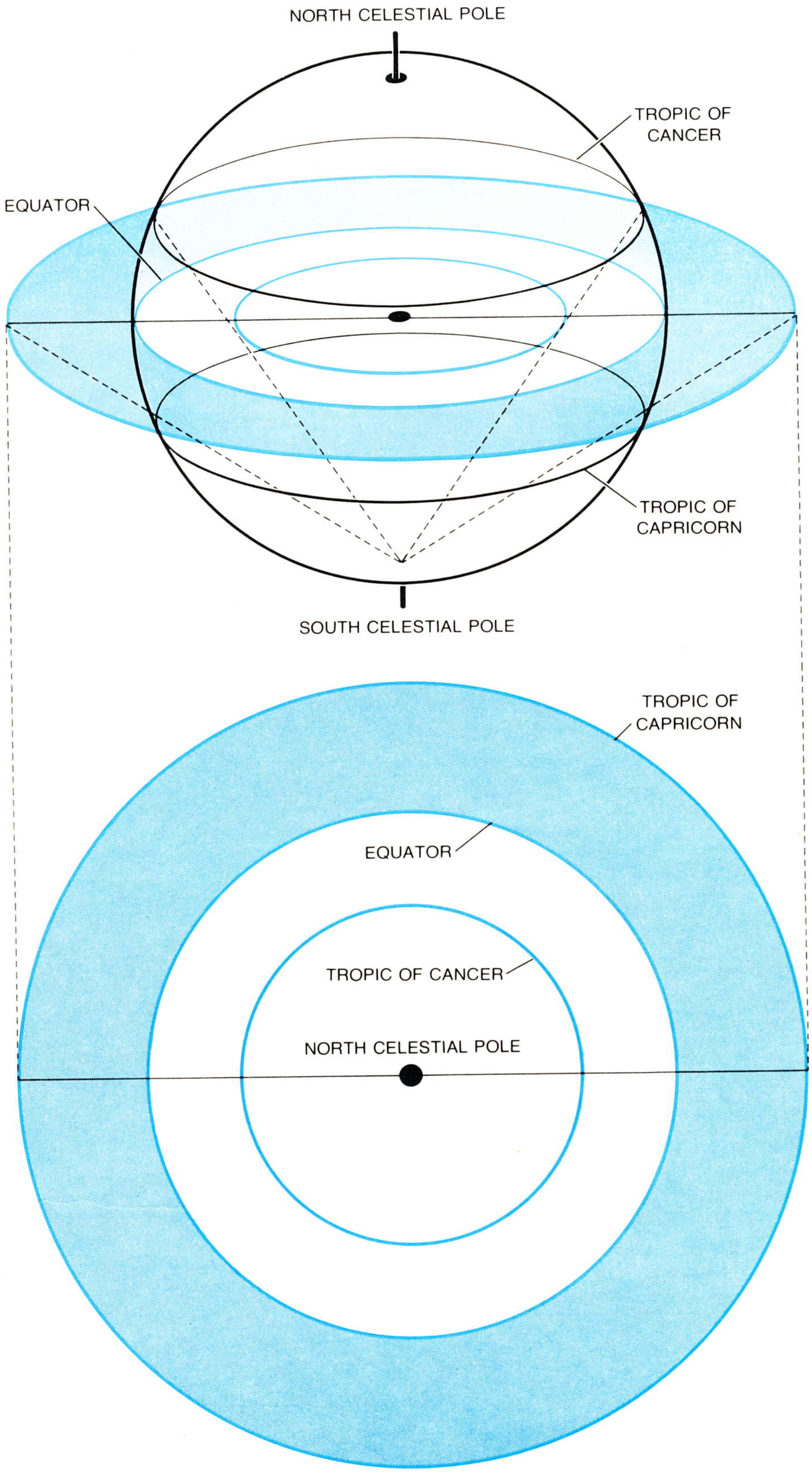
MOORISH ASTROLABE of the 13th century has raised knobs on the rete to assist the observer in rotating it. Both the front (*photograph at left*) and the back (*photograph at right*) of the instrument are shown to illustrate the placement of the rete and the alidade. All astrolabes on this page are in the collection at the National Museum of History and Technology of the Smithsonian Institution.

the date within the year. If the stars were visible by day, it would be easier to appreciate the apparent movement of the sun against the stellar background. This movement is of course a consequence of the earth's motion around the sun; as the earth proceeds along its orbit the sun appears to shift with respect to the stars. It is therefore often convenient to speak as though the earth were at rest in the center of a vast sphere on which all the celestial objects are situated. The stars and even the planets are at such immense distances in comparison with the size of the earth that the celestial sphere is a reasonable convention, as long as one is concerned only with the direction of the celestial objects from the observer.

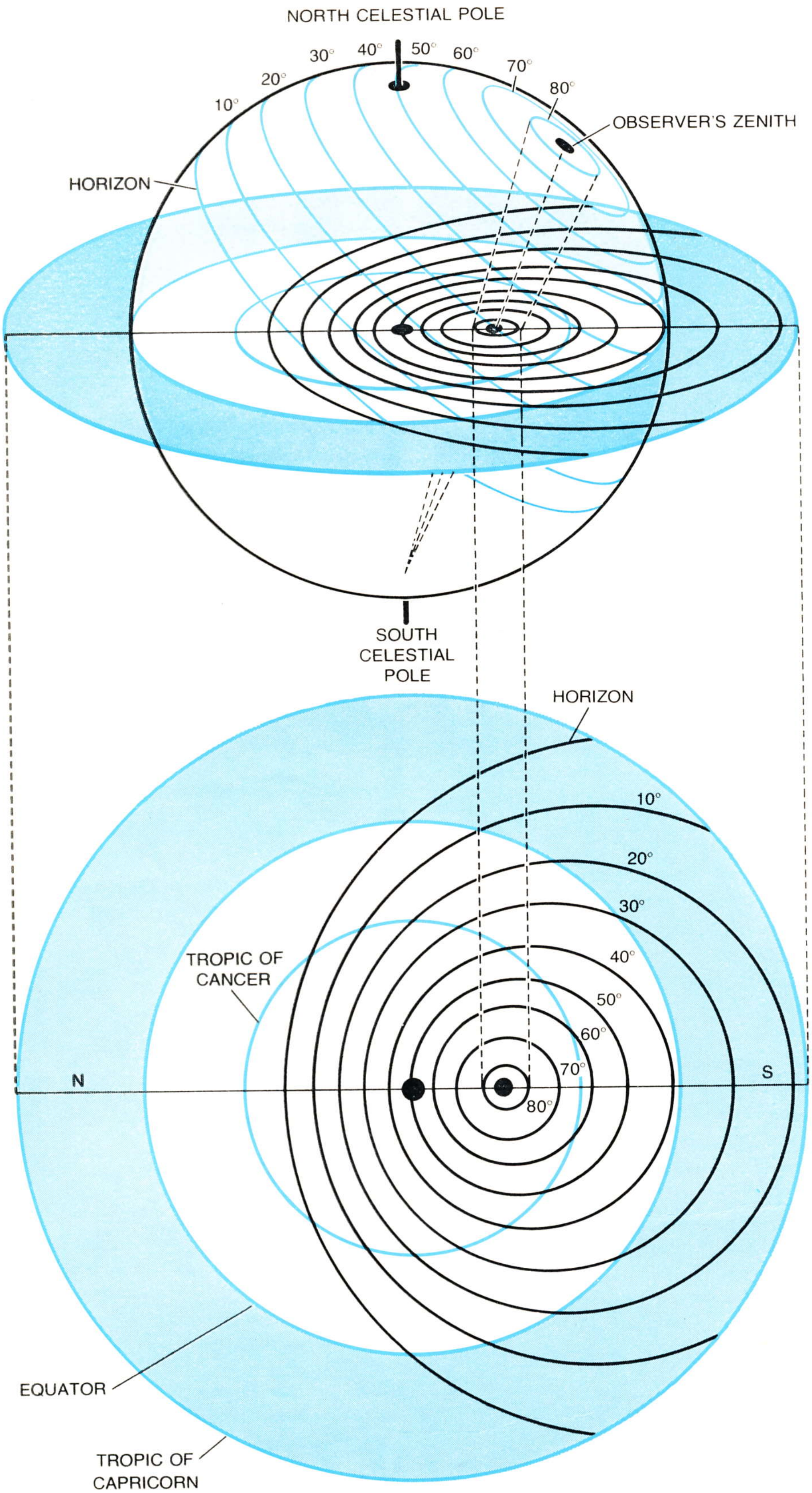
The path of the sun on the celestial sphere is the ecliptic, and the sun completes one circuit of the sky along this path in a year. The planets appear to travel in a band of sky several degrees on each side of the ecliptic; this band is the zodiac. It is possible to give the approximate position of the sun on the ecliptic (its place in the zodiac) for any date of the year. Leap years present a small problem, but it is not a very difficult one, since the accuracy required is only a relatively large fraction of a degree.

The calendar scale of the astrolabe has engraved on it the days and the months. There is also a zodiac scale, usually concentric with the scale of dates, which correlates the dates with the sun's position on the ecliptic. The sun's position can be given as a celestial longitude from zero degrees to 360 degrees, reckoned from some suitable point of origin. In the Middle Ages a variant of this system was used: the zodiac was divided into 12 signs. Each sign was 30 degrees in length and had been named after a prominent constellation. In actuality the constellations had long previously moved into neighboring signs as a consequence of the slow precession of the equinoxes, which in turn is due to a conical movement of the earth's axis. Partly because of precession, and partly because the time it takes the earth to go around the sun once is not exactly 365¼ days, there are small shifts in the sun's position for any particular date as the years pass. These shifts can be taken care of without much difficulty by the rules of the calendar. On an astrolabe, however, it could not easily be done, and a medieval calendar scale is likely to be 10 or 11 days out of register with one of today.

The front of the astrolabe is more important than the back. It has two principal parts. One, the rete, is a fretted plate,



STEREOGRAPHIC PROJECTION OF EQUATOR AND TROPICS shows how these circles on the celestial sphere (*top*) are projected onto the astrolabe plate (that is, onto the mater or one of the climates) or onto the rete. On most astrolabes the plane of the equator (or a plane parallel to it) is taken to be the plane of the projection. A line is extended from the south celestial pole to the desired point on the celestial sphere (in this case one of the tropics or the equator). The point where this line intersects the plane of the projection is the location of that celestial point on the map. A series of such points is charted to yield the coordinate lines. The equator and tropics are at right angles to the axis of the projection. As a result they turn out to be circles that are concentric and centered on the point representing the north celestial pole (*bottom*). Pin goes through the north celestial pole.



STEREOGRAPHIC PROJECTION OF ALMUCANTARS, or circles of equal altitude concentric with the observer's zenith and parallel to the horizon, makes circles on the plane of the projection. They do not, however, have a common center. In the illustration the observer's zenith is 40 degrees north of the equator. His horizon and almucantars are first shown as they appear on the celestial sphere (*top*). The stereographic projection has the property that circles on a sphere remain circles when they are projected onto a flat plane. In projection all the centers of the almucantars lie on the line (*NS*) that runs through both north pole and observer's zenith (*bottom*). Line is the projection of observer's meridian.

which like the rest of the astrolabe is usually made of brass. It overlies an unperforated circular plate. The rete (from the Latin word meaning "net") is a representation of the heavens. The tips of small pointers mark the positions of the brightest stars, an off-center circle represents the ecliptic, and there are also parts of three circles representing the celestial equator and the tropics of Cancer and Capricorn. Through the center of the rete is a pin around which it can rotate. The pin, which also holds the alidade on the back, is kept in place by a wedge passing through a hole in the point of the pin. The thicker end of the wedge was traditionally in the form of a horse's head, and thus the wedge was often called "the horse." If any durable transparent material had been readily available at the time, the rete would probably have been made of it; anyone today who wanted to build a simple astrolabe could use a sheet of plastic to make the star map.

The other principal part of the astrolabe is the plate under the rete. It is graduated with a series of circles and straight lines representing coordinate lines that are fixed with respect to a given observer. The center of the astrolabe, around which the rete turns, represents the north celestial pole, around which the stars appear to turn. Concentric with it are the Tropic of Cancer, the celestial equator and the Tropic of Capricorn. These circles can be represented both on the rete and on the plate below it. On the plate there is a line representing the observer's horizon and a point for his zenith. There is a set of almucantars, or circles of constant altitude, above the horizon and encircling the zenith. There are also lines of constant azimuth, which appear as arcs of circles radiating from the zenith and running down to the horizon.

Clearly the distance separating the pole and the observer's zenith on the astrolabe plate depends on the geographic latitude of the observer. If he lived at the North Pole, the two points should coincide, whereas if he lived at the Equator, the two should be separated by whatever represents 90 degrees on the astrolabe plate. The necessity of having a different plate for every latitude at which the instrument was to be used was always a source of chagrin to the astrolabist. He would have a plate for his own latitude, and he might have as many others as he was likely to need on his travels.

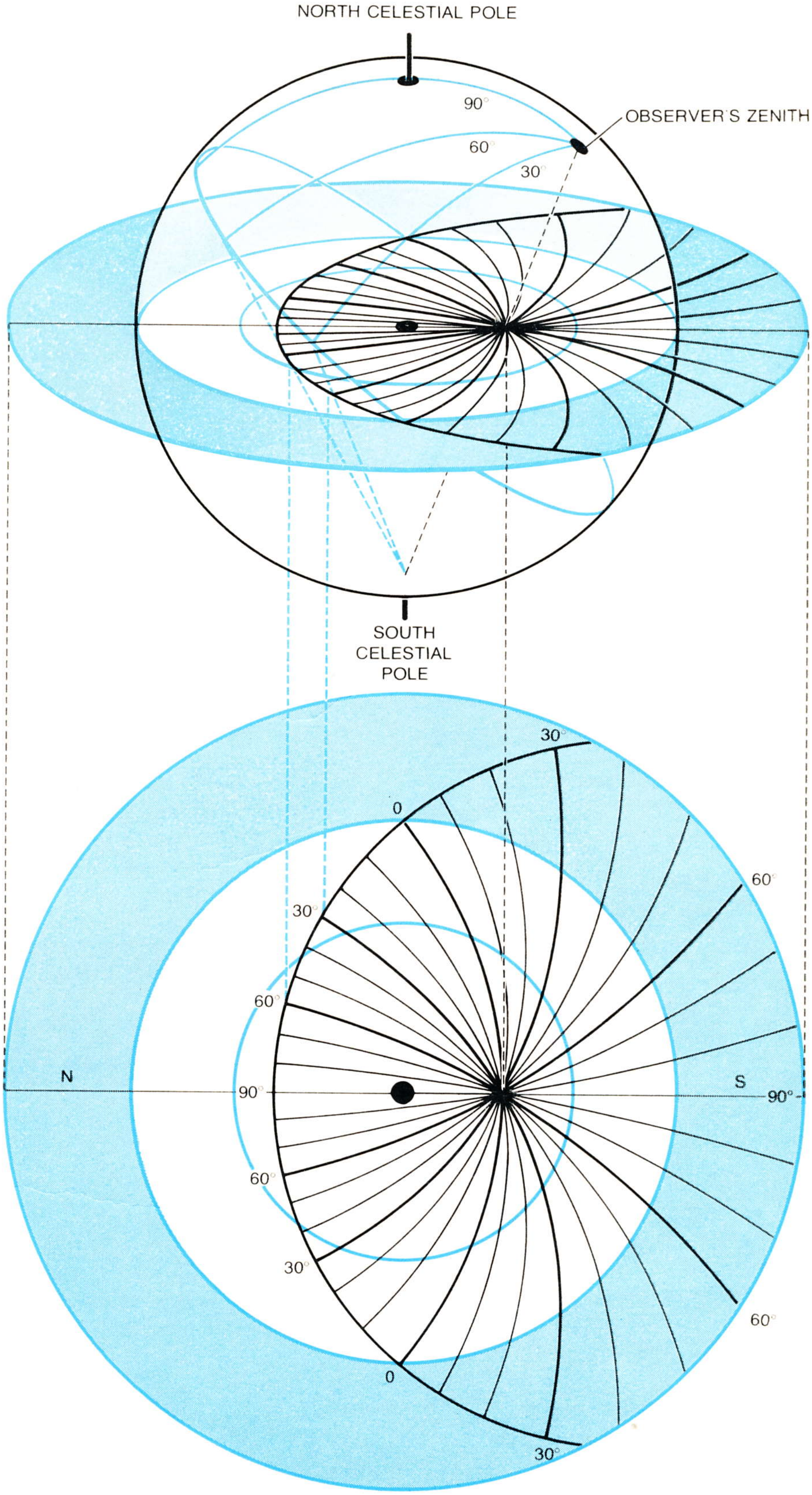
Such plates were often called climates by an obvious extension of meaning. An

astrolabe might have as many as four, five or even more climates, each plate being engraved on both sides and all being stacked in the mater, or main body, of the astrolabe. They fitted under the rete and were secured by the pin and horse [*see illustration on page 97*]. There were astrolabes that could be used at any latitude with a single plate, but they were not easy to use nor were they ever common.

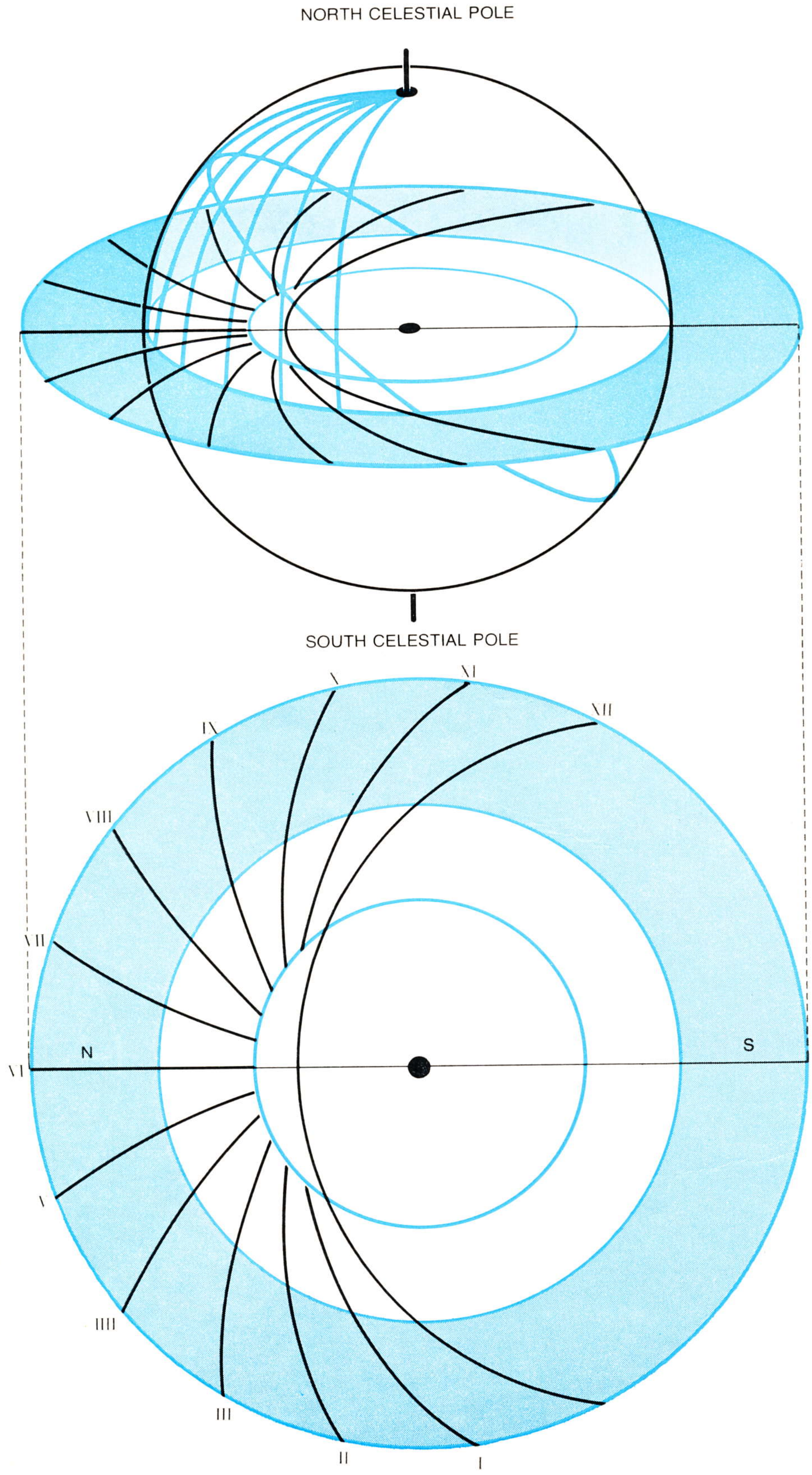
How are the stars and the coordinate lines on the celestial sphere mapped onto the rete and the climates? Suppose the observer was at the center of a large hemispherical dome on which the almucantars and the coordinate lines of constant azimuth were drawn at intervals of five or 10 degrees. Through this series of lines he would be able to see the stars of the night sky, which would move with respect to the lines because of the daily rotation of the earth. If the observer were to take a long-exposure photograph, the pinpoints of starlight would trace out arcs of concentric circles rotating around the north celestial pole. (In the true medieval manner we shall overlook the needs and prejudices of those living in the Southern Hemisphere.)

Just as it is possible to make a flat map of a terrestrial globe, so it is possible to map the two spheres introduced here: the fixed network of coordinate lines and the moving sphere of the sky. There are certain necessary practical requirements if the maps are going to be made of brass and are to serve at all times. If the two maps are to be arranged so that one pivots around a fixed point of the other, as with an astrolabe, then this point should be one of the poles, preferably the north pole if the instrument is to be used in the Northern Hemisphere. Furthermore, the projections of both maps should be alike for all positions of the rete and the plate with respect to each other; a map projection would be no good at all if it meant that the rete had to be distorted as it rotated.

The stereographic projection was admirably suited to the needs of the astrolabist. It has the property that circles on a sphere remain circles when they are projected onto a flat plane, and that the angles between intersecting circles on the sphere remain unchanged when they are projected. Although there are reasons for suspecting that other conventions were used in earlier times, the convention that was almost universally followed with small astrolabes was to project stereographically from the south



STEREOGRAPHIC PROJECTION OF LINES OF EQUAL AZIMUTH is a series of great circles that stretch from the horizon to the zenith. Hence they cut the horizon circle, and the almucantars (*not shown*), at right angles (*top*). Angles between intersecting circles on a sphere remain unchanged when they are stereographically projected onto a flat plane. Therefore on the astrolabe plate the lines of equal azimuth will be arcs of circles that cut the lines of the horizon, and the almucantars (*again not shown*), at right angles. Most astrolabes show only the lines of equal azimuth that would appear above observer's horizon (*bottom*).



STEREOGRAPHIC PROJECTION OF HOUR ANGLES places the last set of coordinate lines on the plate of the astrolabe. The entire cycle of one day is divided into 24 hours. When the time was reckoned in unequal hours, as it is here, the period of daylight and the period of night, regardless of their duration, were both divided into 12 equal parts. Thus the hours of the day were not equal in length to the hours of the night. The hour lines were usually drawn only below the horizon line. Those portions of the concentric circles of the equator and the tropics are divided into 12 equal parts, beginning with the points of intersection with the west horizon. Corresponding points are connected then with smooth curves.

pole of the celestial sphere onto the plane of the equator. A line was extended from the south pole to the desired object on the celestial sphere; the point where this line intersected the plane of the projection was the location of the celestial object on the map. A series of such points was mapped to yield the coordinate lines.

With this stereographic projection, the closer a southern star is to the south celestial pole, the farther it will be from the north celestial pole on the plane of the projection, that is, on the rete. The projection of the entire celestial sphere is infinite in extent. In practice the rete is almost invariably made only a little larger than is necessary to accommodate the Tropic of Capricorn. Stars on the rete are represented by the tips of brass pointers. In principle these could be bent after a time to allow for the precessional movement of the earth's axis (although such allowance is not worth bothering with over periods of half a century or less). The bending is more likely to happen by accident than by design, however, and the pointers were usually made as rigid as possible. On the rete the circles of the tropics and the equator are not much needed, since they also appear on the plate below, and so they simply serve largely as supports for the star pointers.

The equator and the tropics are at right angles to the axis of the projection. As a result they turn out in projection to be circles that are concentric with the rete and centered on the north pole (represented by the pin). Moreover, if any degree graduations were to be put on the equator of the celestial sphere, they would lie uniformly on the projected equator. Neither of these properties belongs to the most important circle on the rete, namely the ring that represents the ecliptic. The center of the ecliptic ring differs from the center of the equator and the tropics because the plane of the earth's equator is inclined at an angle of 23½ degrees with respect to the plane of the earth's orbit. Longitudes are measured along the ecliptic from the vernal equinox, one of the two points where the ecliptic crosses the equator. This is the beginning of the sign of Aries; when the sun is at the "first point of Aries," day and night are of equal duration.

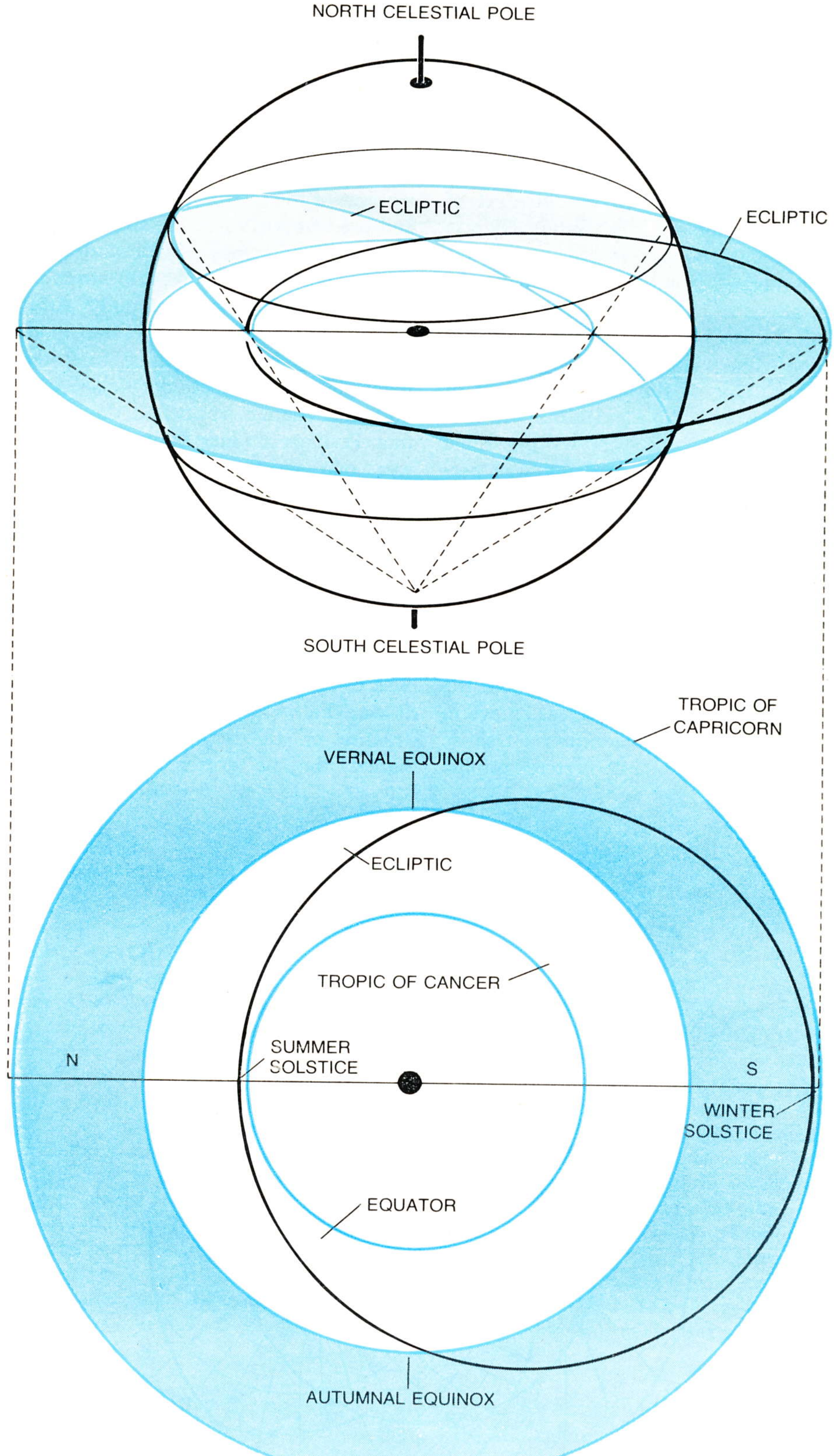
At the vernal equinox the sun is passing from south of the equator to the north and is heading through Aries into the sign of Taurus on its progression around the ecliptic. When it reaches its most northerly point of the ecliptic at the summer solstice, 23½ degrees north of

the equator, it leaves Gemini and passes into Cancer, hence the name of the tropic in the Northern Hemisphere at the latitude of +23½ degrees. As the sun continues its course along the ecliptic it eventually enters Libra as it again crosses the equator, although this time it is passing from north to south. This it does at the autumnal equinox, when again day and night are of equal duration. The sun reaches the winter solstice as it enters Capricorn 23½ degrees south of the equator, hence the name of the tropic in the Southern Hemisphere at a latitude of −23½ degrees. The sun's annual path as a whole is indicated by the outermost rim of the ecliptic ring on the rete.

How is the ecliptic ring on the rete constructed? All that is needed is to plot the points of the summer and winter solstices [*see illustration at right*]. Since in the stereographic projection circles remain circles on the map, these two points define the diameter of the ecliptic circle. The geometric center of the ecliptic will lie midway between the two points. The ecliptic circle, when constructed, will cross the equator at the points corresponding to the equinoxes. (It so happens that the geometric center of the ecliptic always falls at such a point that the angle made at the equinoxes from the center of the ecliptic to the center of the rete is twice 23½ degrees or, more precisely, twice whatever value is accepted for the angle the ecliptic makes with respect to the equatorial plane.)

The almucantars are drawn on the astrolabe plate below the rete in much the same way. The horizon of the observer is inclined to the celestial equator by 90 degrees minus the geographic latitude of the observer [*see illustration on page 100*]. To find the two points determining each of the almucantars, it must be remembered that the almucantars are no longer great circles in planes passing through the center of the earth; they are small circles parallel to the horizon. When they are drawn, the result is a series of circles around, but not concentric with, the observer's zenith. All their centers lie on the meridian.

The lines of equal azimuth are much more difficult to construct. They are a series of great circles stretching from the horizon to the zenith, and cutting the horizon circle and the almucantars at right angles. Since the stereographic projection leaves angles unchanged, the lines of equal azimuth on the astrolabe plate will be arcs of circles that retain this property. In general, astrolabes



STEREOGRAPHIC PROJECTION OF THE ECLIPTIC is used for the rete instead of for the astrolabe plate. The ecliptic is the apparent annual path of the sun on the celestial sphere as seen from the earth. The Equator of the earth is tipped at an angle of 23½ degrees from the plane of the ecliptic, so that this angle is preserved on the astrolabe rete. All that is needed to draw the ecliptic is to plot the point of the summer solstice on the Tropic of Cancer and the point of the winter solstice on the Tropic of Capricorn. These two points define the diameter of the ecliptic circle, whose center lies midway between. Ecliptic crosses equator at points corresponding to vernal equinox (first day of spring) and autumnal equinox (first day of fall). Ecliptic is divided into 12 signs of zodiac starting at the point representing vernal equinox. The lines dividing ecliptic radiate from the north celestial pole.

show only those parts of the lines of equal azimuth that appear above the observer's horizon [*see illustration on page 101*].

Before we turn to some uses of the astrolabe, what of its history? The theory of the stereographic projection can be traced back to one of the greatest of Greek astronomers, Hipparchus. He was born about 180 B.C. in Nicaea, not far from modern Istanbul, and he made observations from Rhodes and Alexandria. Unfortunately most of what we know about him comes from secondary sources. One of the most important of these sources is the Alexandrian astronomer Ptolemy, who was writing some four centuries later. Ptolemy was perhaps the greatest astronomer of the ancient world. His most important book, now known as the *Almagest*, makes no mention of the planispheric astrolabe. There are, however, references in his *Planisphaerium* to the "spider" of the "horoscopic instrument," suggesting that an instrument with something like the later form of the astrolabe was known in his day. The *Planisphaerium* is a treatise not on the astrolabe but on stereographic projection. It is known only from a Latin translation by Hermann of Carinthia (A.D. 1143).

Other scholars besides Ptolemy refer to the astrolabe, but many of the references are cryptic. The oldest surviving account of the instrument's construction and use was written in the sixth century by John Philoponos of Alexandria. A century later Severus Sebokht wrote on the subject in the Syriac language. After this time the instrument became moderately well known, judging from the many different treatises devoted to it in both the Islamic world and the Christian. Perhaps the first European treatise was one written by Hermann von Reichenau, or Hermann der Lahme (the Lame), a monk of Reichenau who died in 1054.

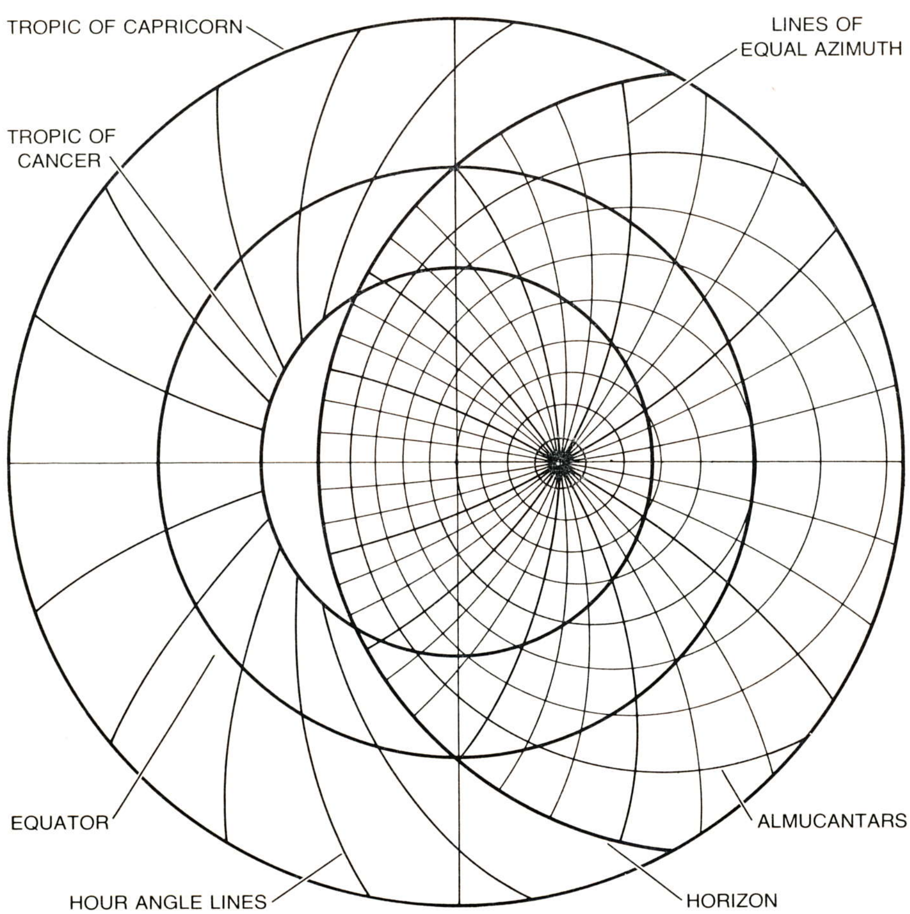
Much better known in medieval Europe was a work originally written in Arabic by Māshā'allāh, who is believed to have been an Egyptian Jew. It was translated into Latin by 1276, and it was the basis of the only good early treatise on the astrolabe in English, namely the one written a century later by none other than Geoffrey Chaucer.

His work, titled *A Treatise on the Astrolabe*, is dated about 1392. It survives in more than two dozen early manuscripts. In some of them it has the subtitle *Bread and Milk for Children*. The subtitle was probably provided by a scribe who was surprised at Chaucer's opening remarks in a work that would have been generally regarded as hardtack for adults. In a modern rendering the work begins:

"Little Lewis my son, I well perceive signs of your ability to learn the sciences of number and proportion, and I also have in mind your earnest request especially to learn the contents of the treatise on the astrolabe." Chaucer goes on to outline the contents of the treatise, which in fact seems never to have been completed. He explains the need for a work in English, and he mentions his debt to earlier astronomers. It is unfortunate that his English is about as difficult for the ordinary modern reader as Latin was for Lewis.

By the 16th century the advent of printing and the steady improvement in techniques of engraving for publication had given rise to a number of magnificent new treatises on the astrolabe. These were in turn partly responsible for some striking advances in the art of the instrument maker. Astrolabes became larger, more decorative and more finely and accurately engraved. Nevertheless, allowing for differences in the language of the inscription, there was little or nothing about the typical astrolabe of the early 17th century that would not have been immediately familiar to an astrolabist of a thousand years earlier. The oldest surviving dated instrument is believed to date from A.D. 927/8. This particular astrolabe also carries a signature that is difficult to decipher, but which could be an Arabic form of a Greek name (Bastulos or Nastulos).

Before the end of the 13th century the planispheric astrolabe was known and used from India in the east to Islamic Spain in the west, and from the Tropics to northern Britain and Scandinavia. Variations in the general style of decoration are usually characteristic of the country and period of origin. The star pointers of the earliest retes, for instance, are usually of a simple dagger shape engraved only with the name of the star. At the other extreme later Indo-Persian astrolabists would often work the rete into an intricate and highly symmetrical foliate pattern, a difficult thing to do with what is essentially a star map having an asymmetrical natural arrange-



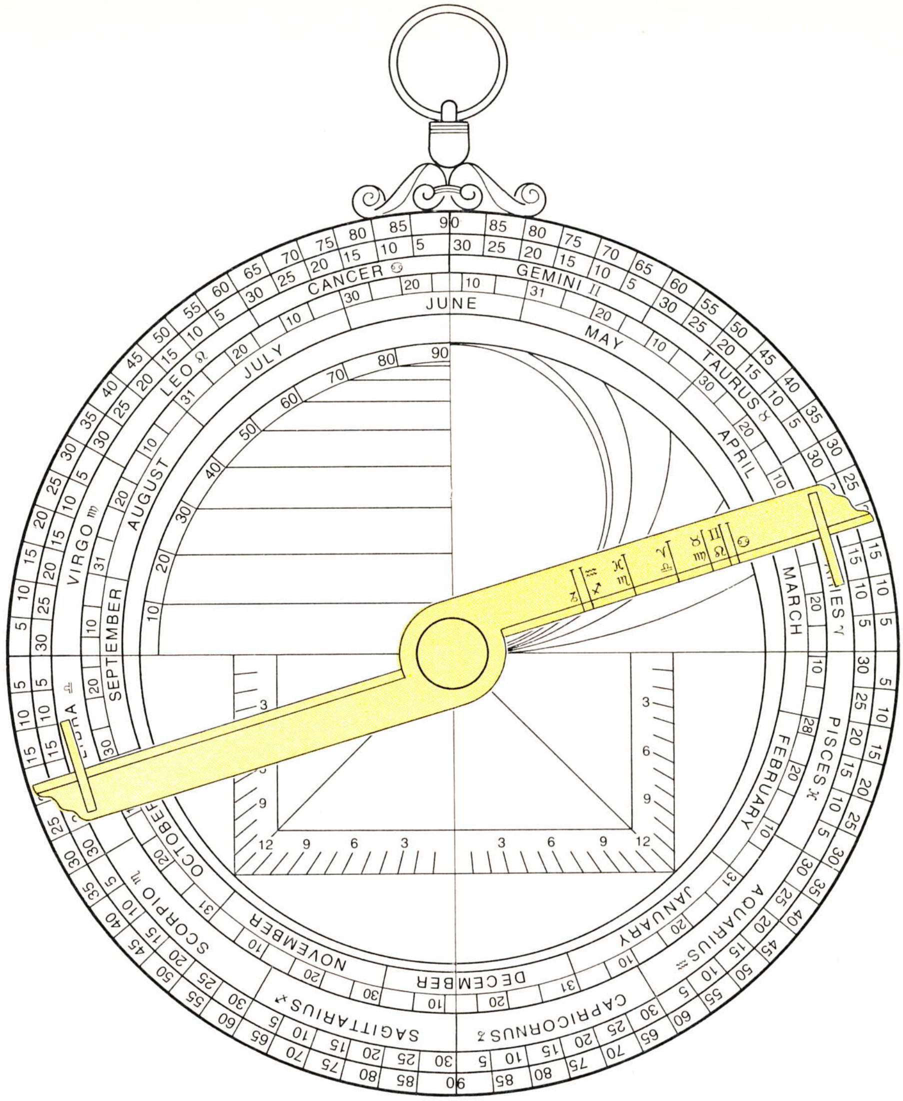
COMPLETE ASTROLABE PLATE shows all the coordinate lines as they appear with respect to one another on a climate. This illustration is a composite of all the stereographic projections shown individually in the series of illustrations on pages 99, 100, 101 and 102.

ment. Astrolabe makers throughout the eastern world often damascened their instruments with silver and gold. It is interesting to trace from their surviving signed work successive generations of the same family. The family might all, for example, have worked at a center such as Lahore, and thus perhaps have had connections with the Mogul court. Persian instruments tended to be extremely ornate, filled with fine ornamental engraving.

In the West the style of the rete is usually reminiscent of contemporaneous styles of church architecture. The style of written inscription is similar to the style of Western manuscripts in general, and is highly characteristic of the period in which it was done. There is good evidence that many astronomers the world over made their own instruments, although there was scarcely any important center of learning that did not at one time or another have its specialist workshops turning out instruments professionally. European instruments were rarely signed with the maker's name during the Middle Ages, a time when anonymity was considered no vice. By the 16th century European astrolabes were often signed.

The physical size of most astrolabes is between three and 18 inches, although much larger ones are found in a number of rather different forms as the dials of astronomical clocks. The use of the astrolabe as a clock dial goes back to classical antiquity, when the rete was made to rotate once daily by waterpower. After the invention of the purely mechanical escapement at the end of the 13th century, astronomical clocks were to be found in most large European cathedrals. In a typical arrangement the star map and the map of coordinate lines of the conventional astrolabe change places, the coordinate lines being made into the rete and the stars being painted on a plate behind it. Usually the stars were made to rotate and the rete was fixed, but sometimes these roles were reversed. A model of the sun is occasionally found on the ecliptic of the star map; it is moved along the ecliptic manually, or by a mechanism, so that it completes one circuit of the ecliptic in a year. In order to judge the time from such a dial one must be familiar with at least the basic principles of the use of the astrolabe.

The chief purpose of the astrolabe was for telling the time. First the altitude of the sun or of a star was found by employing it as an observing instrument.



BACK OF THE ASTROLABE carries the alidade and other information necessary to the observer. Around the rim of the example shown is a scale of degrees for measuring the altitude of a celestial body with the alidade. Immediately inside the rim the 12 signs of the zodiac are listed and divided into 30 degrees each. The scale ot the months and the days inside the zodiac scale correlates the position of the sun on the ecliptic with the correct date. It is not concentric with the other circles to allow for the sun's nonuniform motion along the ecliptic. The design of the interior portion of the astrolabe back varies widely with the individual instrument. Here the quadrant at upper left contains horizontal lines from the degree markings; their distances from the horizontal diameter of the astrolabe correspond to the sine of the altitude of an object above the horizon. The quadrant at upper right contains lines for computing the time in unequal hours directly, independently of the front of the astrolabe. These lines are used in conjunction with the graduations on the alidade. The two quadrants at bottom contain the "shadow squares." These could have been used in conjunction with a gnomon to get the cotangent or the tangent of the altitude of an object above the horizon. If they were accurately and completely divided, which they rarely were, they provided a means of measuring altitudes more precise than sighting with alidade.

Then, assuming that the observer knew where the sun or the star was on the rete, the rete was revolved until that point coincided with the almucantar for the appropriate altitude. (It is assumed that the observer knew which climate to choose for his latitude and on which side of the meridian line the object fell.) The refraction of the atmosphere, which changes the apparent position of objects in the sky, and which is greater the nearer they are to the horizon, was ignored. The sun's approximate position on the ecliptic for any day of the year is found from the calendar scale on the back of the astrolabe.

Once the rete is in the correct position, the observer can find his local time according to any one of several conventions. If the circumference of the astrolabe is marked in degrees, 15 degrees correspond to an hour. Noon will be when the sun is toward the top of the instrument, midnight when it is toward the bottom, 6:00 A.M. when it is to the

left and 6:00 P.M. when it is to the right. Imagine now a great circle joining some object in the sky to the north celestial pole. The angle that this great circle makes with the meridian is the hour angle of the object. As a consequence of the stereographic projection, a rule lying on a line passing through the center of the astrolabe and the point of the instrument representing the object makes an angle with the vertical diameter (the meridian line) equal to the hour angle of the object. The hour angle is so named because it can provide one with a measure of time through its change as the earth rotates. It is usually quoted in hours, minutes and seconds rather than in degrees of arc.

A number of different kinds of time can be told from an astrolabe. The first is sidereal time, or time by the stars, which is defined as the hour angle of the first point of Aries. If the day is counted from zero hours to 24 hours beginning at midnight, 12 hours will have to be added to the count for sidereal time, because at the vernal equinox the first point of Aries (which is at that time the position of the sun) will cross the meridian at local noon.

A second kind of time is true solar time: the hour angle of the sun regardless of its position with respect to the stars. There is another and more familiar type of solar time called mean solar time, which postulates a "mean sun" moving around the equator (rather than the ecliptic) at a uniform rate throughout the year, and making one complete circuit in exactly a year like the true sun. The earth moves around the sun in an ellipse with the sun at one focus, and it travels faster in its orbit the closer it is to the sun. Therefore from the earth the true sun seems to speed up and slow down in its course around the ecliptic. Thus the true sun and the mean sun move not only along different paths but also at different rates. In order to convert from observed true solar time to the more useful mean solar time, one must apply a correction known as the equation of time. It is based on knowledge of the earth's motion in its orbit and it can be found in reference books. The correction for the equation of time was scarcely ever applied before the 17th century. In order to convert mean solar time to the local time at some standard location such as Greenwich, the observer needs to know his geographic longitude, and again that adjustment was seldom made.

A third kind of time is time measured in unequal hours. The ordinary man in the Middle Ages divided the period of daylight into 12 equal parts and the period of night into 12 equal parts regardless of the actual length of day and night. The length of the day-hours would obviously equal the length of the night-hours only when the sun was at one of the equinoxes. Many astrolabe plates include unequal-hour lines. In order to avoid their being confused with the almucantars, the unequal-hour lines were drawn only below the horizon line [*see illustration on page 102*].

Time in the Middle Ages was often reckoned from sunrise or sunset even when measured in ordinary equal hours. Many astrolabe plates show lines similar in appearance to the lines of unequal hours but which are in fact for measuring the time in equal hours from sunrise or sunset.

Although the astrolabe was primarily an instrument for determining the time, it was an extremely useful adjunct of the astrologer's art. To cast a horoscope for a particular moment of time, an astrologer needs to know the degree of the ecliptic that is on the eastern horizon ("the ascendent"), the degree of the ecliptic that is on the western horizon ("the descendent"), the degree of the ecliptic where it crosses the meridian ("the degree of mid-heaven") and the degree of the ecliptic where it crosses the northward continuation of the meridian, once called the midnight line ("lower mid-heaven"). These degrees are easily read off the ecliptic ring once the rete is correctly positioned for the moment of time that is of interest: perhaps a moment of conception, of birth, of death or of some other important event such as a coronation. Once the four key points of the horoscope have been found, the 12 astrological houses (which are not to be confused with the signs) can be ascertained and the planets can be assigned to them. There are, however, many systems by which the division can be made. These can be found in Chaucer's treatise on the astrolabe.

Like a modern electronic computer, the astrolabe in the Middle Ages was a source of astonishment and amusement, of annoyance and incomprehension. Imprecise as the astrolabe may have been in practice, it was undoubtedly useful, above all in judging the time. The instrument might have been used, more often than not, in the dark, but "dark" is hardly the word to describe the age in which it was so widely known and so well understood.